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Use of the Vaisala Ceilometer for Boundary Layer Height Detection

Presented by:
Mike Gilroy
Puget Sound Clean Air Agency
Seattle, WA

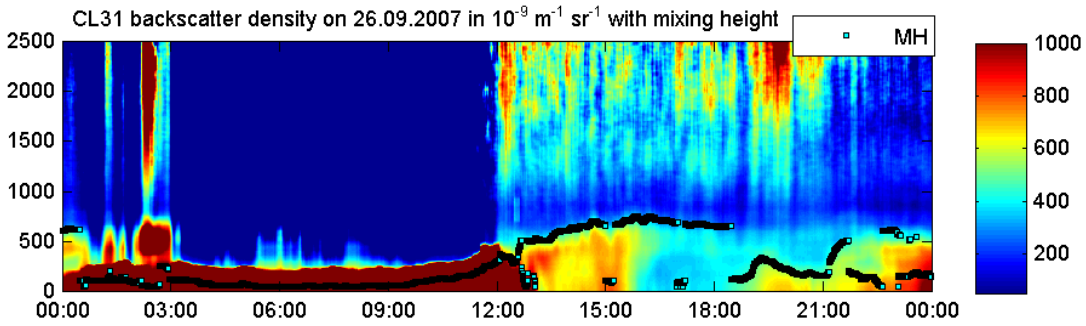
Study Overview

- **Objective is to evaluate technologies to continuously measure the boundary layer (BL) depth for air quality applications.**
- **Instrument chosen was Vaisala CL31 ceilometer. The CL31**
  - **is relatively inexpensive;**
  - **is easy to install and operate; and**
  - **already exists at many airports.**
  - **Scheduled ASOS network upgrade**
- **CL31 is first and foremost a cloud measuring tool.**

CL-31 Installed

Ceilometer

- **The ceilometer works by emitting a laser beam vertically and detecting the reflection of the beam by particles.**
- **The ceilometer measures**
  - **Continuous reflectivity (backscatter)**
  - **Hourly or sub-hourly BL heights from about 2 to 3,000* m agl with a vertical resolution of about 10 m**
  - **BL heights (derived from the backscatter profile)**



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Historical Data Collection Tools

- **Rawinsondes**
  - **Rawinsondes are typically deployed twice daily.**
  - **Expensive**
  - **Small network**
  - **Inadequate for many analysis or model validation needs**

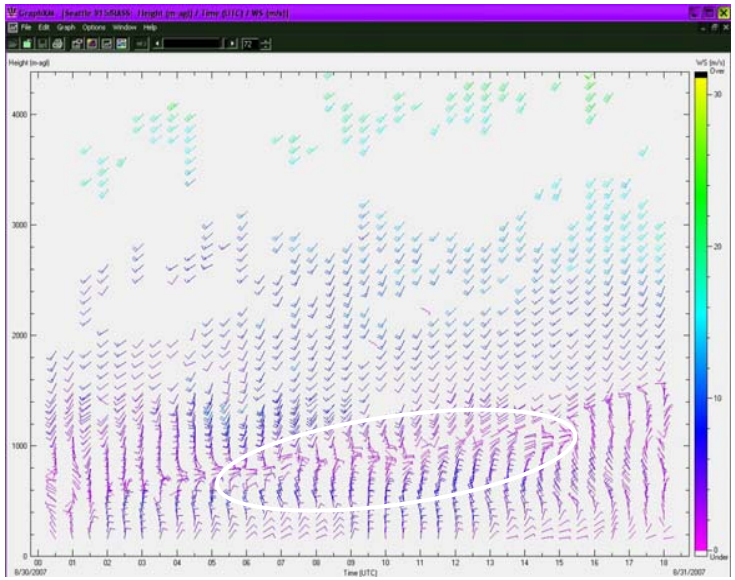
- **RASS/ RWP SYSTEMS**
  - **Expensive**
  - **Fixed site, difficult to install**
  - **Good temporal resolution**
  - **Small network**
  - **Misses lowest layers (SFC-120m)**
  - **Impacted by atmospheric conditions**

RASS/RWP

- **The RWP is a vertically pointing clear air radar that measures**
  - **Hourly or sub-hourly horizontal winds from about 100 to 4,000 m with a vertical resolution of 60 to 120 m depending on settings**
  - **Continuous reflectivity (SNR/Cn2 backscattered signal)**
  - **Continuous vertical velocity**
- **RASS provides vertical profiles of temperature from about 100 to 1,500 m with a vertical resolution of 60 m**

Air Quality Data Needs

- **Vertical Temperature and Wind Measurements are critical to:**
  - **Forecasting**
  - **Data analysis**
  - **Modeling**
  - **Model Validation**
- **All benefit from temporally and spatially resolved BL information.**



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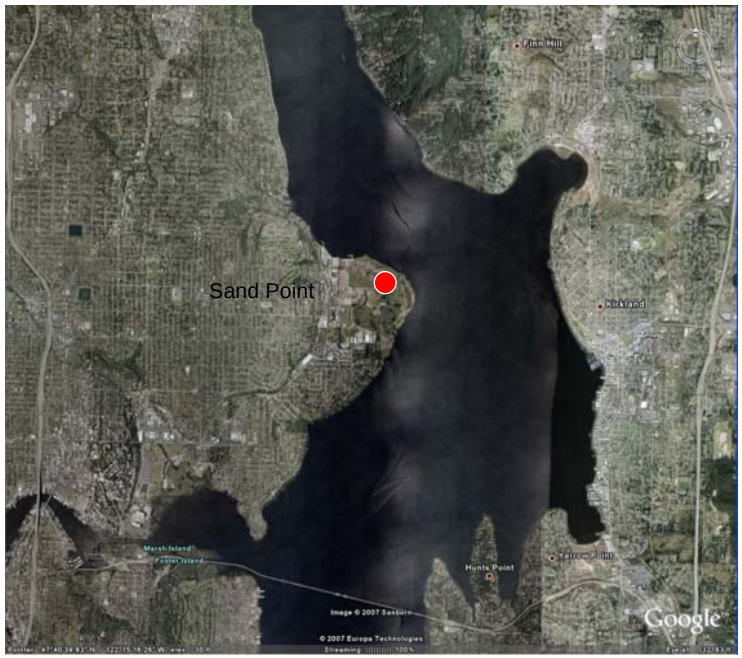
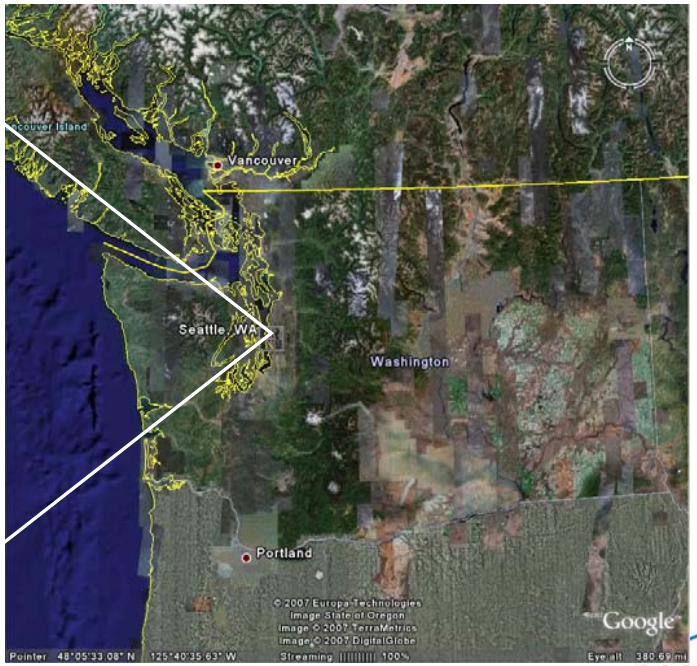
Study Setup

Ceilometer was collocated with a RWP/RASS operated by the Puget Sound Clean Air Agency at the Sand Point station in Seattle –
August 20–September 30, 2007- Nov 1, 2007- Feb 20, 2008

BL heights were derived from the RWP, RASS, and ceilometer and compared statistically and through case-study analysis





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Results – Time Series of BL Heights

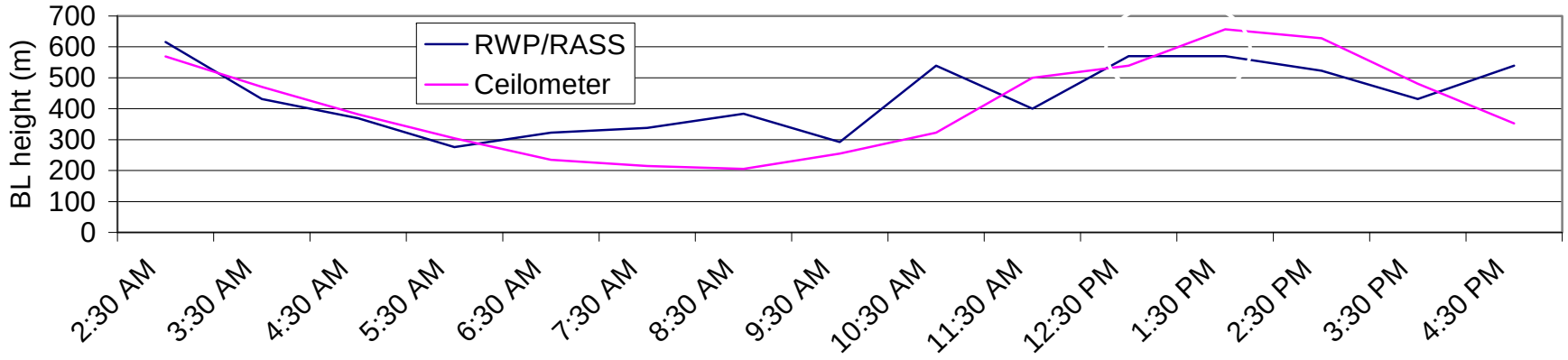
Three cases are the subject of a time series of RWP/RASS and ceilometer BL heights.

- **Case 1. August 29, 2007, 2:30 am - 4:30 p.m. – Good agreement between RWP/RASS and ceilometer heights.**
- **Case 2. September 8, 2007, 3:30 am - 7:30 p.m. – Good agreement between RWP/RASS and ceilometer heights.**
- **Case 3. September 12, 2007 – Poor agreement due to low ceilometer heights early in the day.**

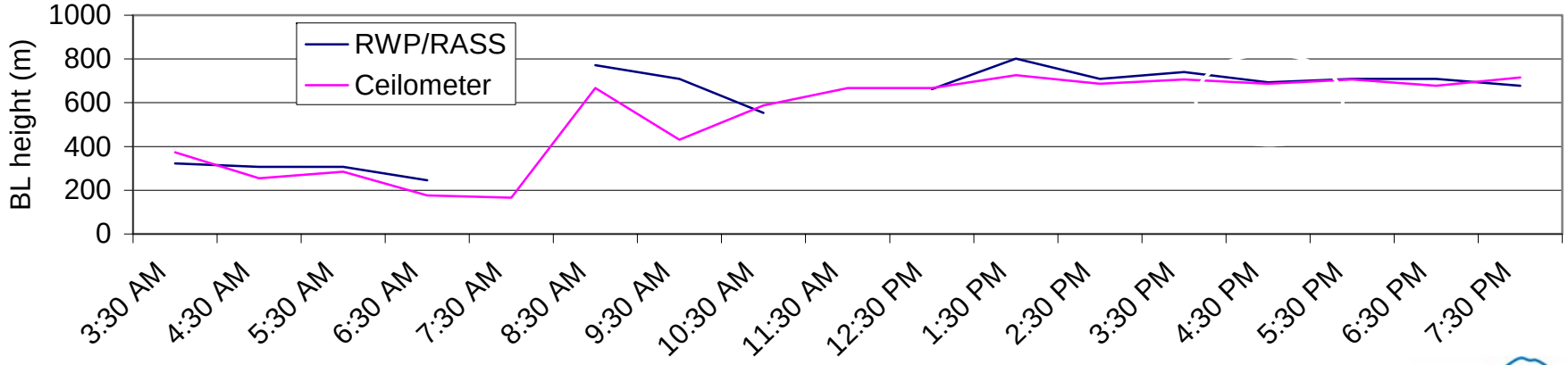
Ceilometer cloud data are included in the analyses.

Results – Time Series for Cases 1 and 2

Case 1



Case 2



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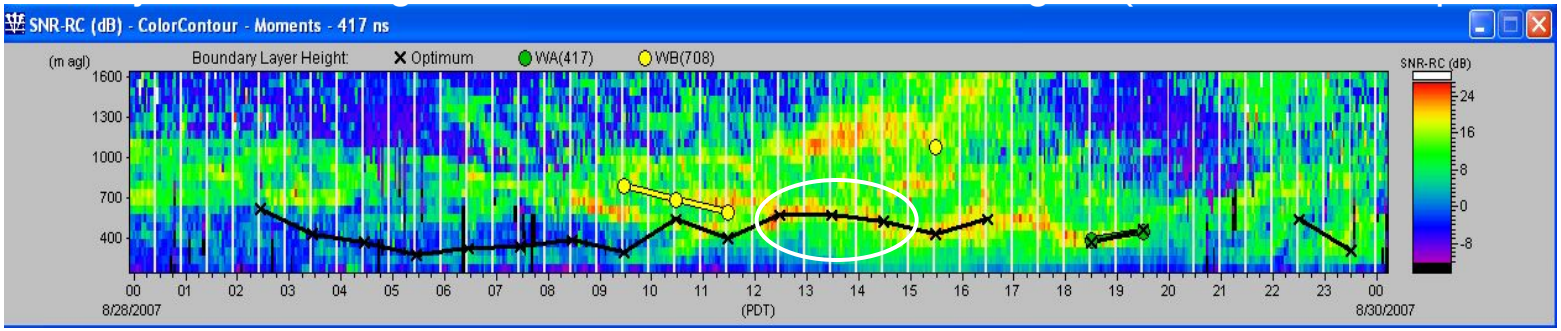
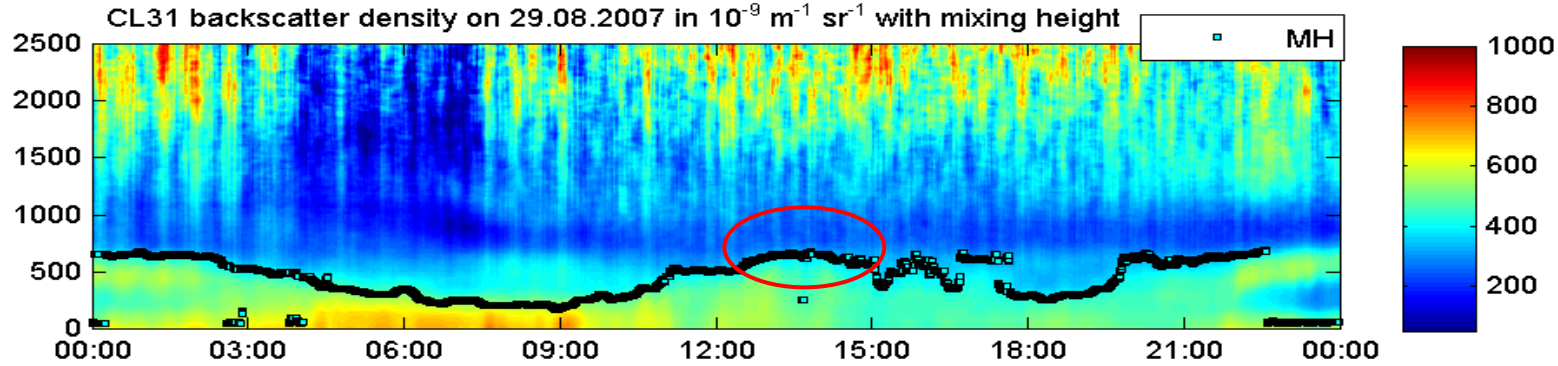
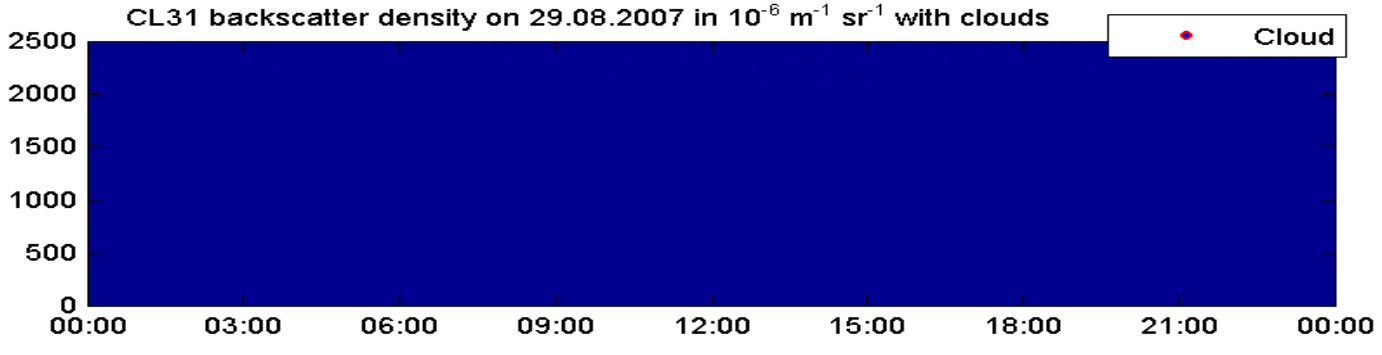
Results – Case 1 (1 of 2)





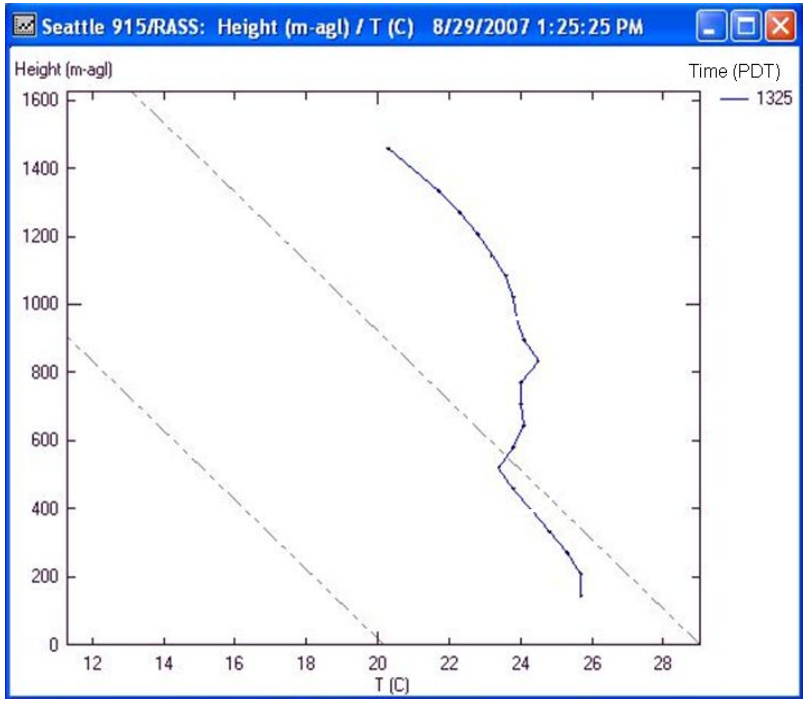
- **Ceilometer clouds (clear skies)**

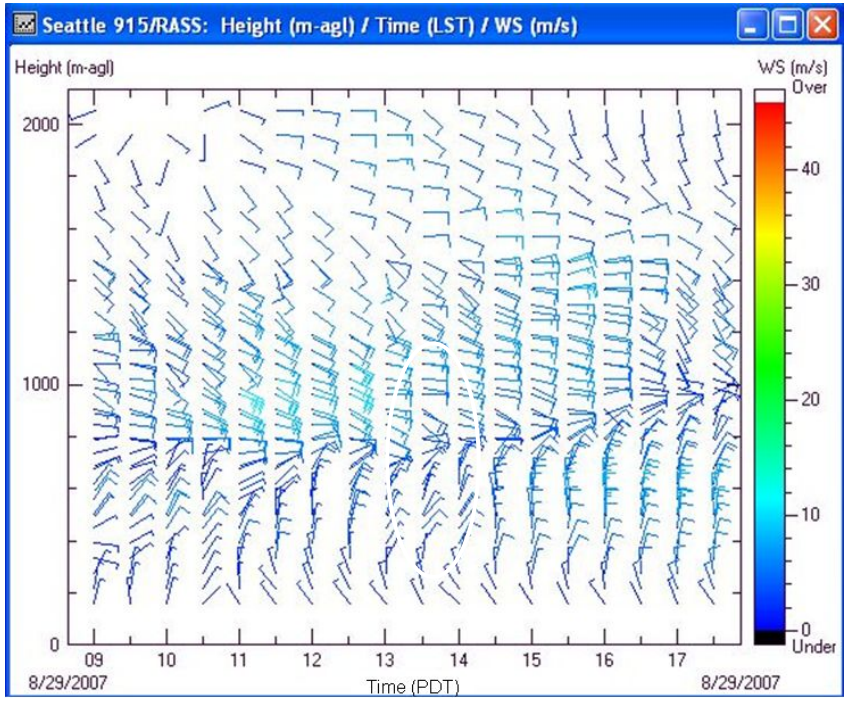


Results – Case 1 (2 of 2)

RASS T_v shows inversions beginning at 600 m and 800 m at 1:30 p.m.

RWP winds shift from northeasterly to east-southeasterly at 750 m at 1:30 p.m.





- **RASS T_v**
- **RWP winds**

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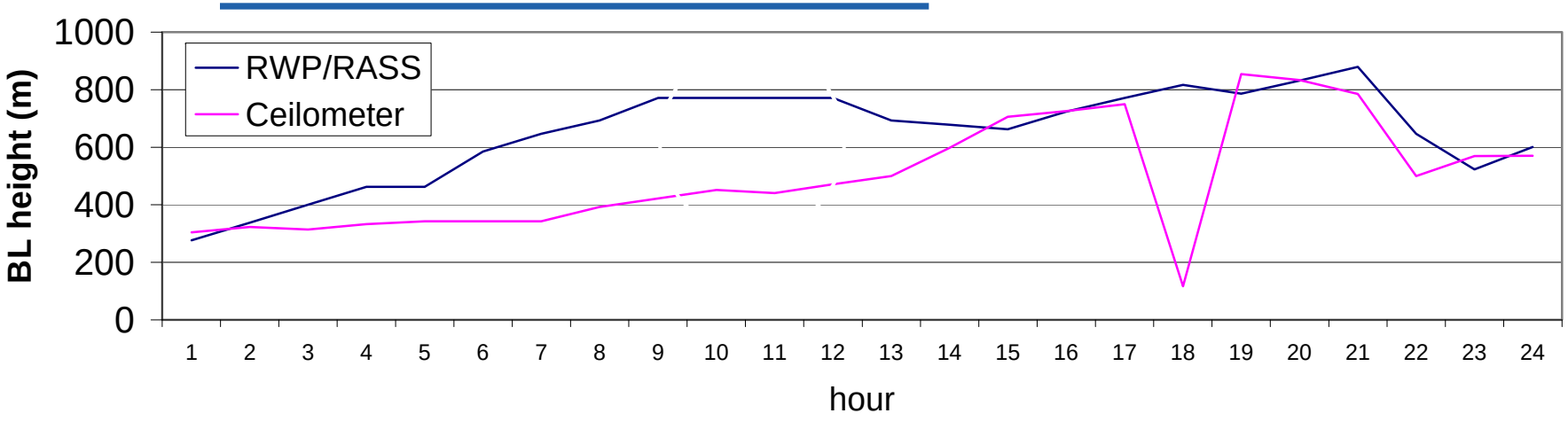
Results – Case 3 (1 of 2)

Case 3,

NEED RASS/RWP plots



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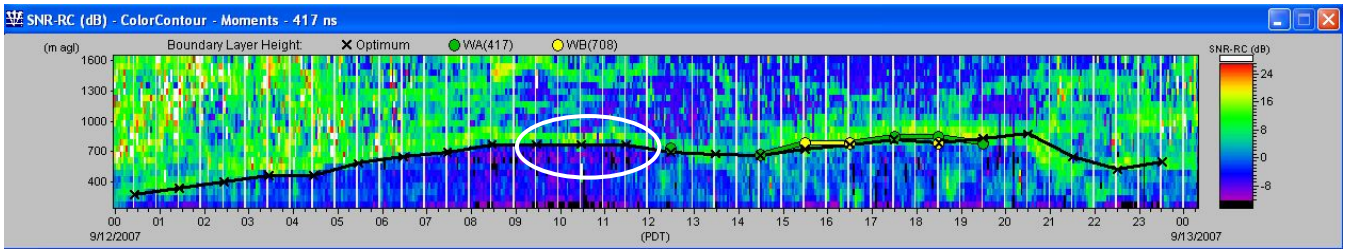
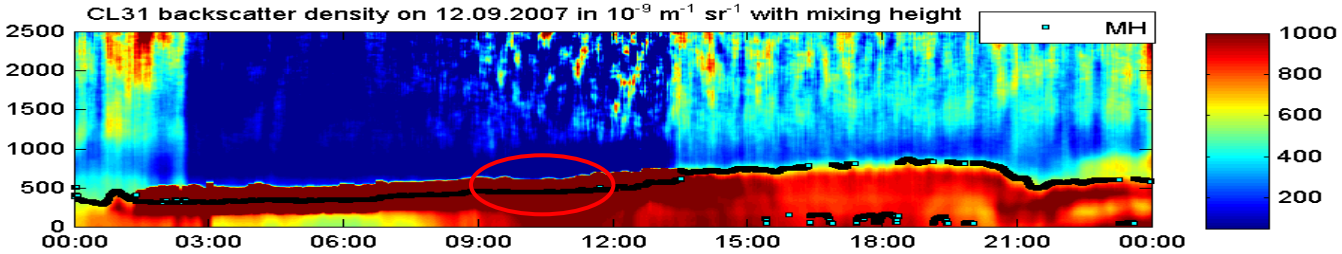
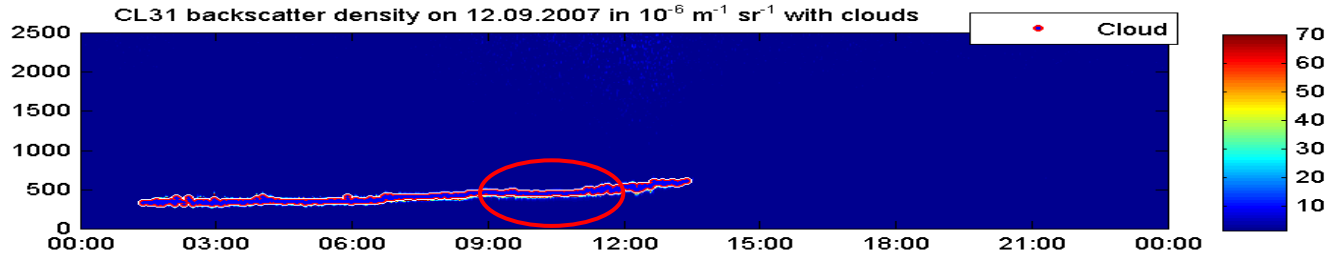
Results – Case 3 (2 of 2)





- **Ceilometer cloud heights (450 m from 10-11 a.m.)**



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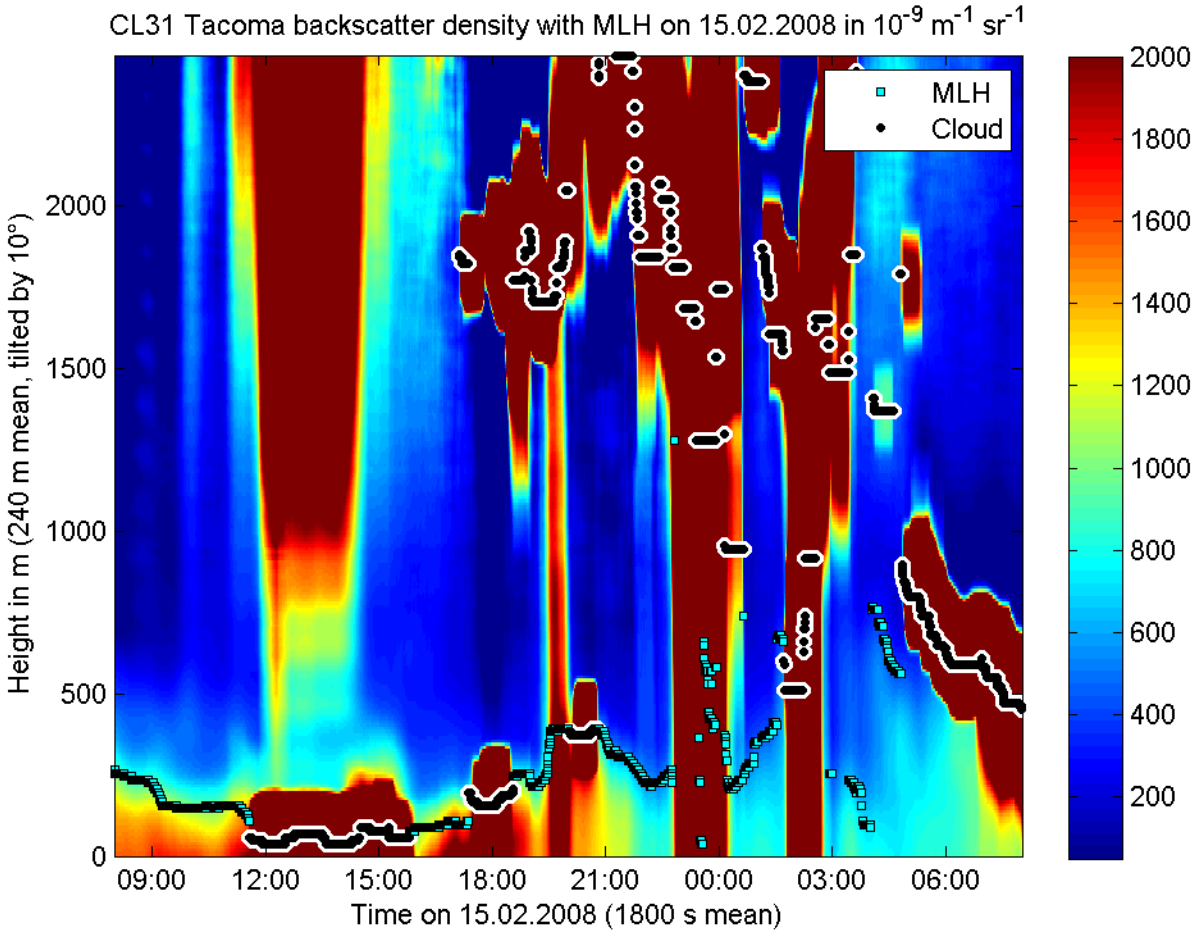
Winter Conditions

- **La Nina did not help!**

15.02.2008



- **Fog in the morning, breaking up as sun rises**
- **Low altitude mixing height day time, occasional precipitation showers**

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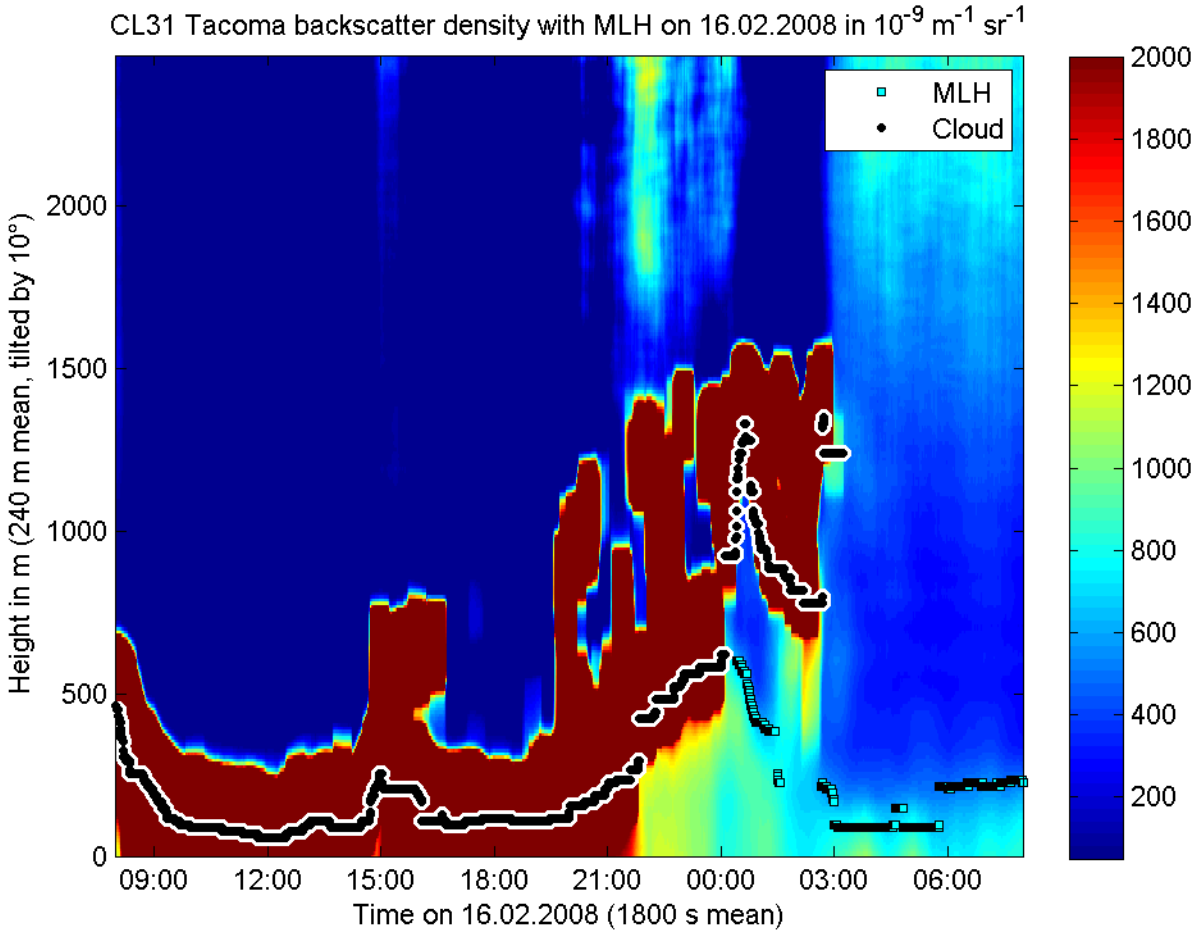
16.02.2008



- **Precipitation during the night and morning**
- **Afternoon cloud layer breaking, low inversion on evening**

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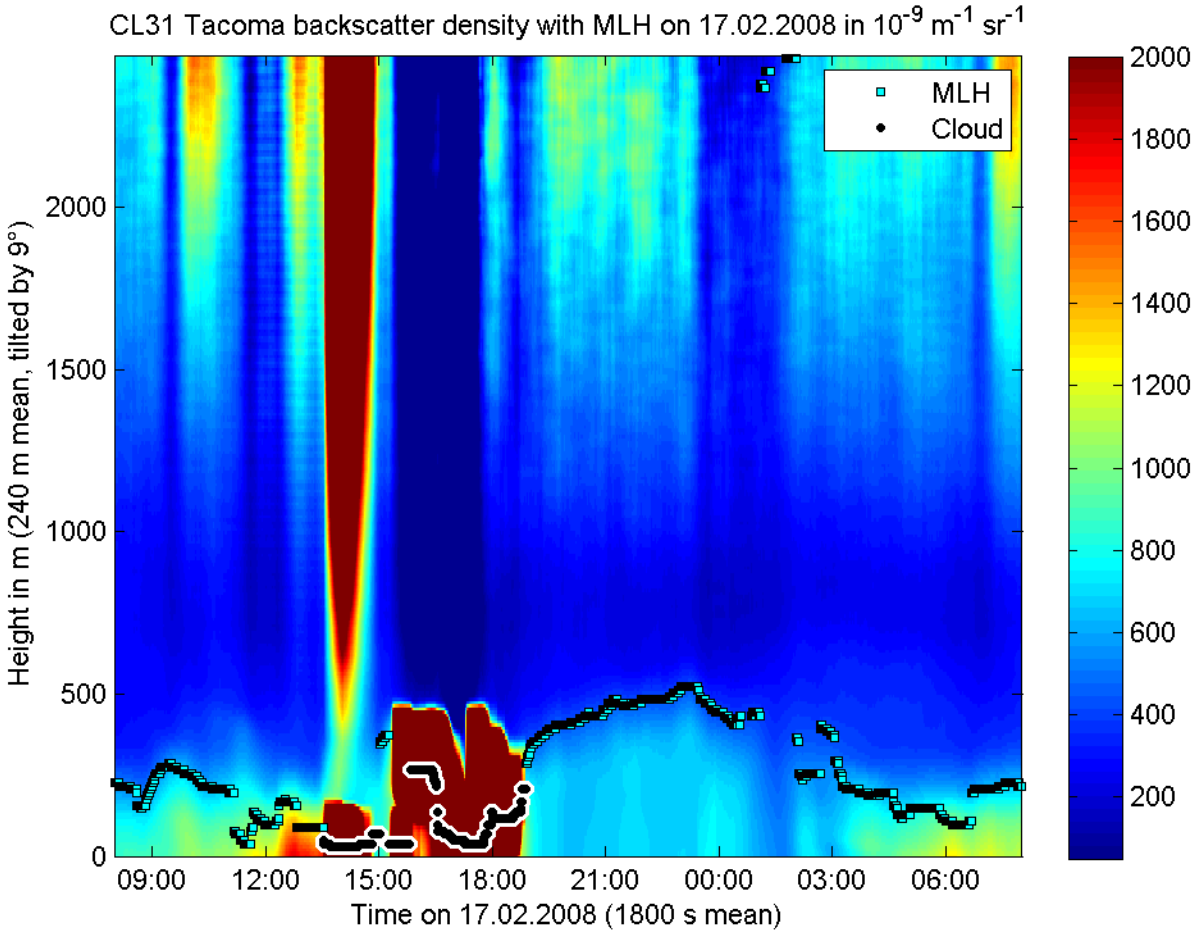
17.02.2008



- **Night time low inversion, fog created in the morning hours**
- **Clouds and showers in morning (at 16-19)**
- **Nice mixing height evolution on afternoon and evening**

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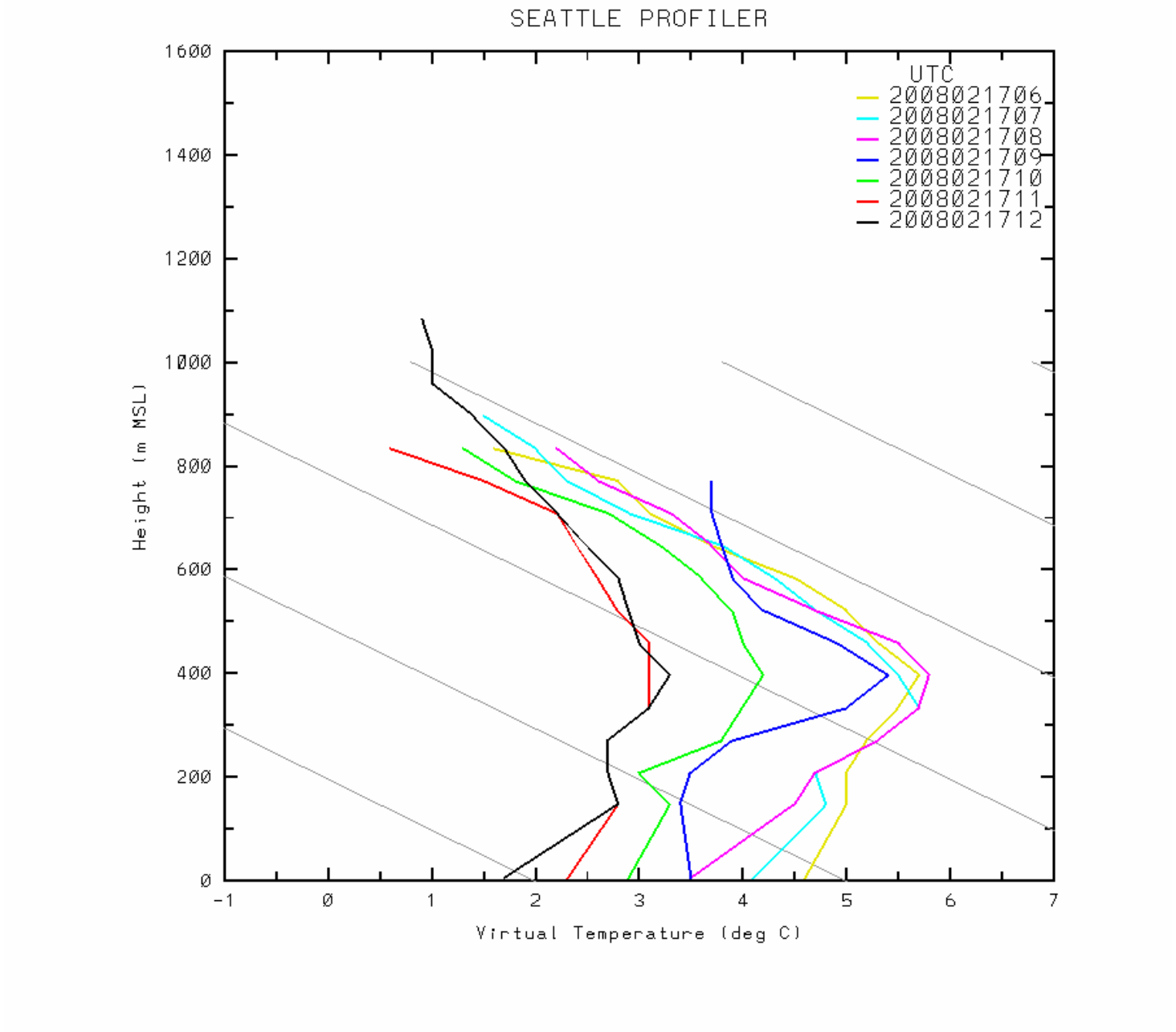
RASS profile



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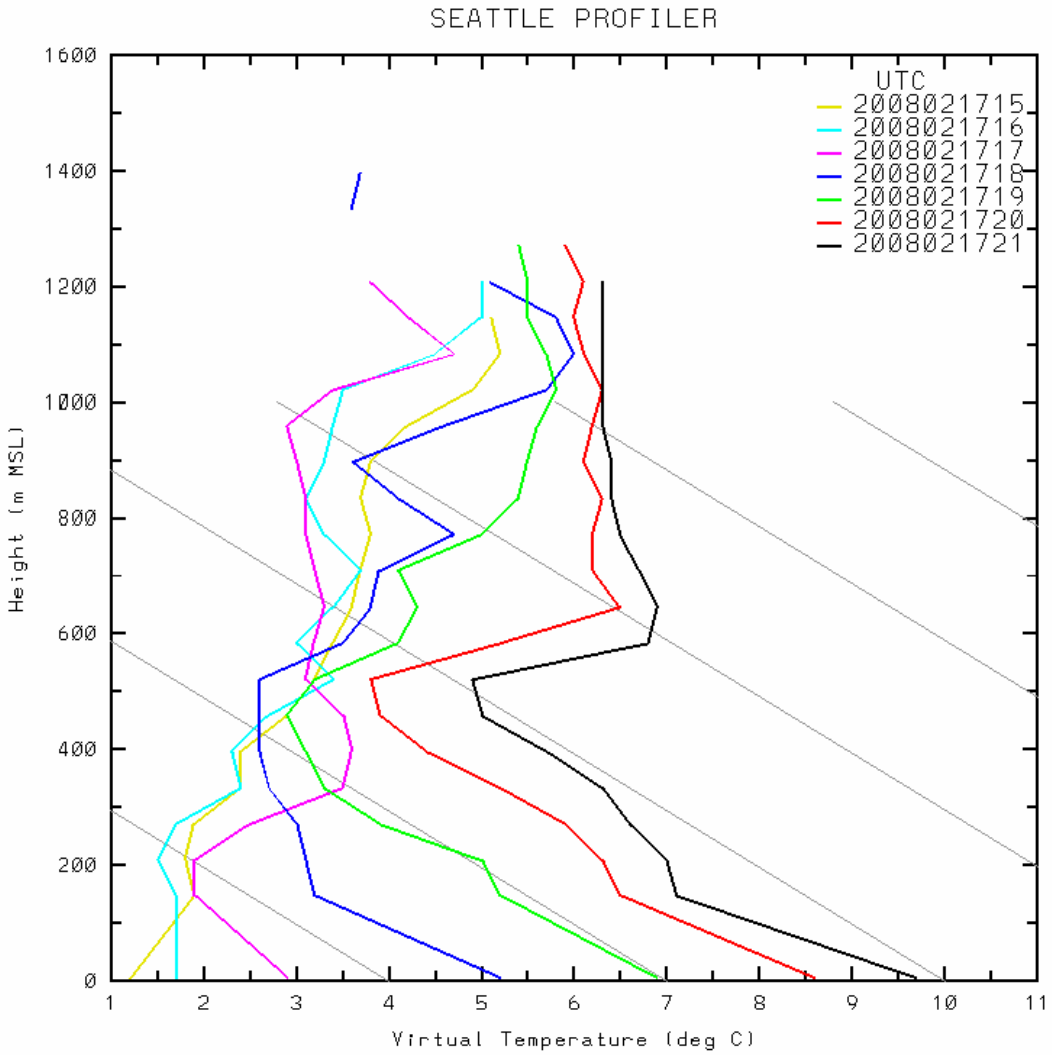
RASS Profile



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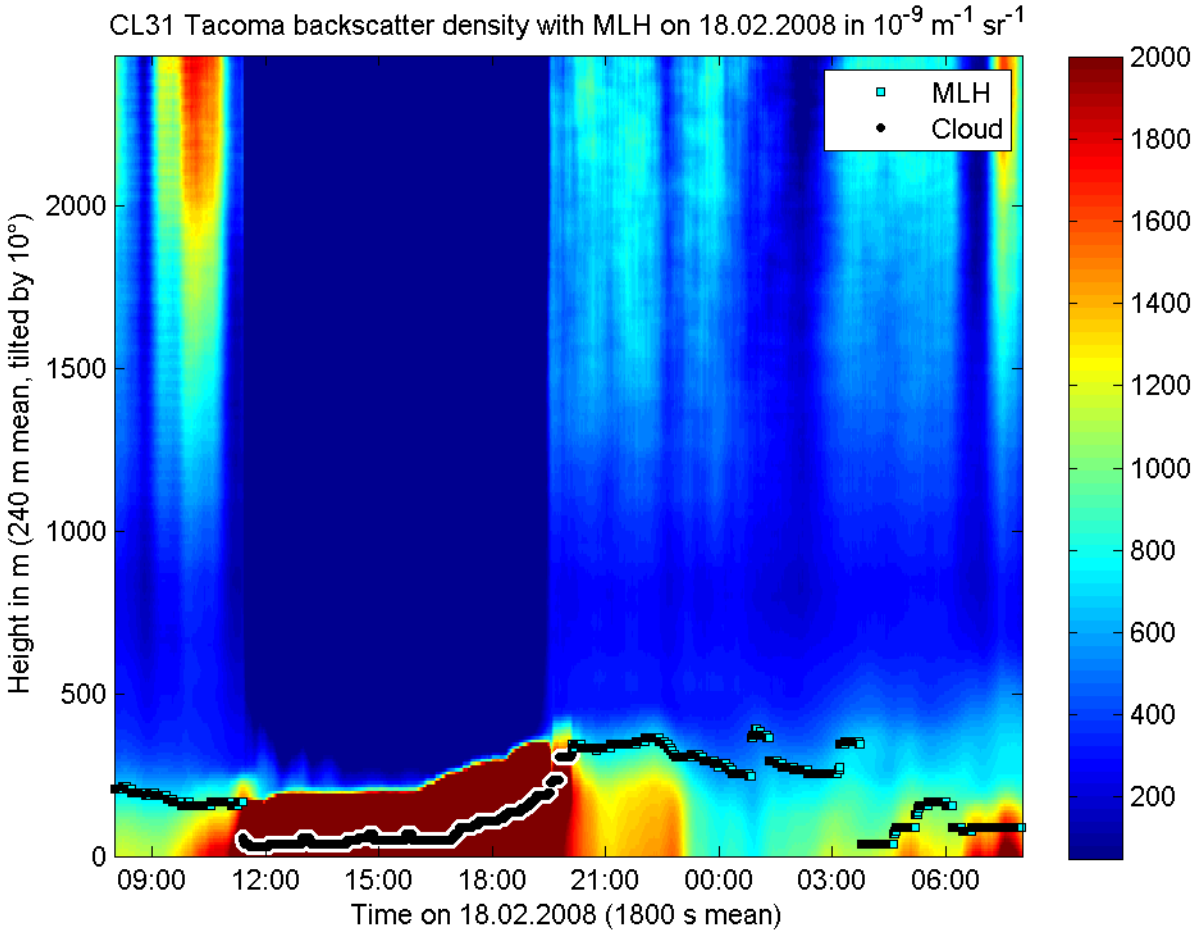
18.02.2008



- **Low inversion and night**
- **Strong fog layer in the morning, breaking up during before noon**
- **Fog starting to create at evening**

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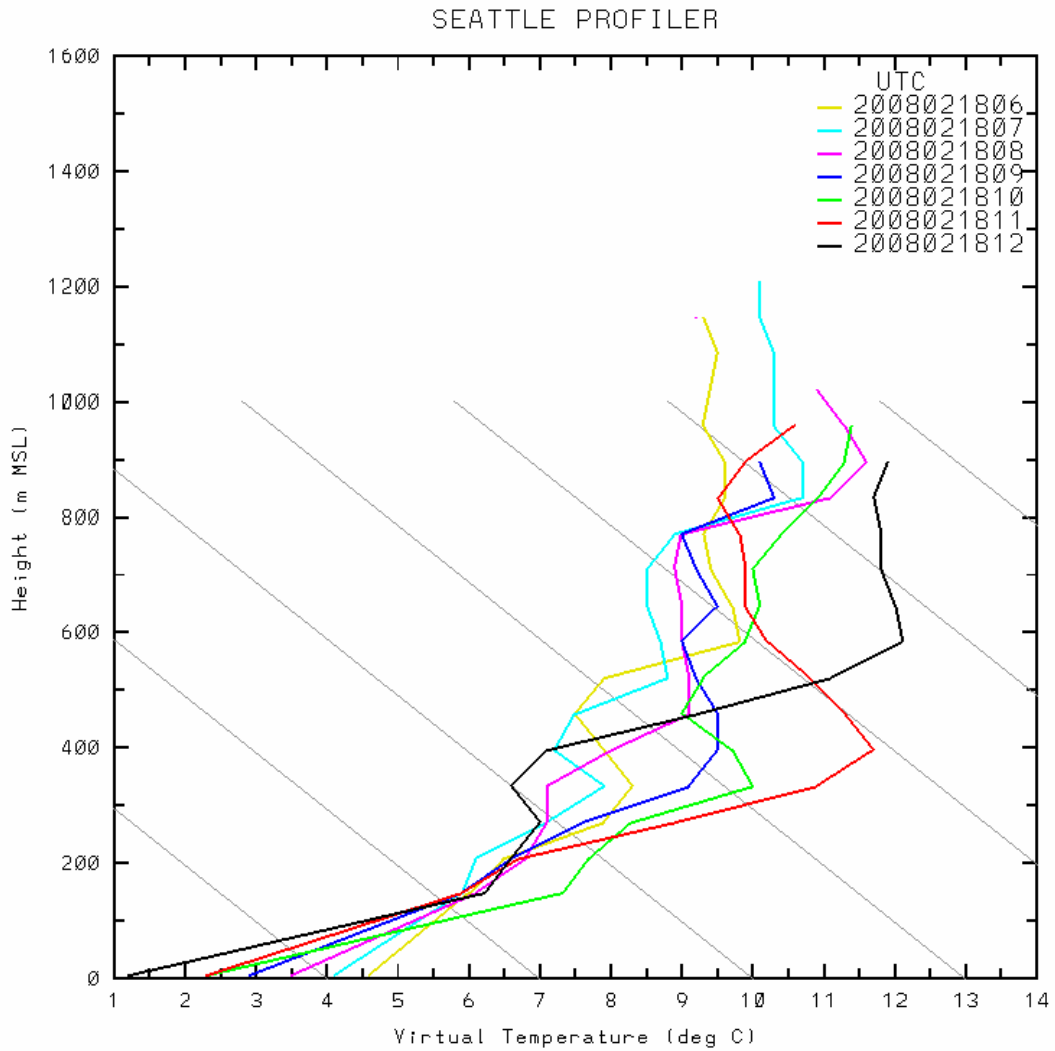
RASS Profile



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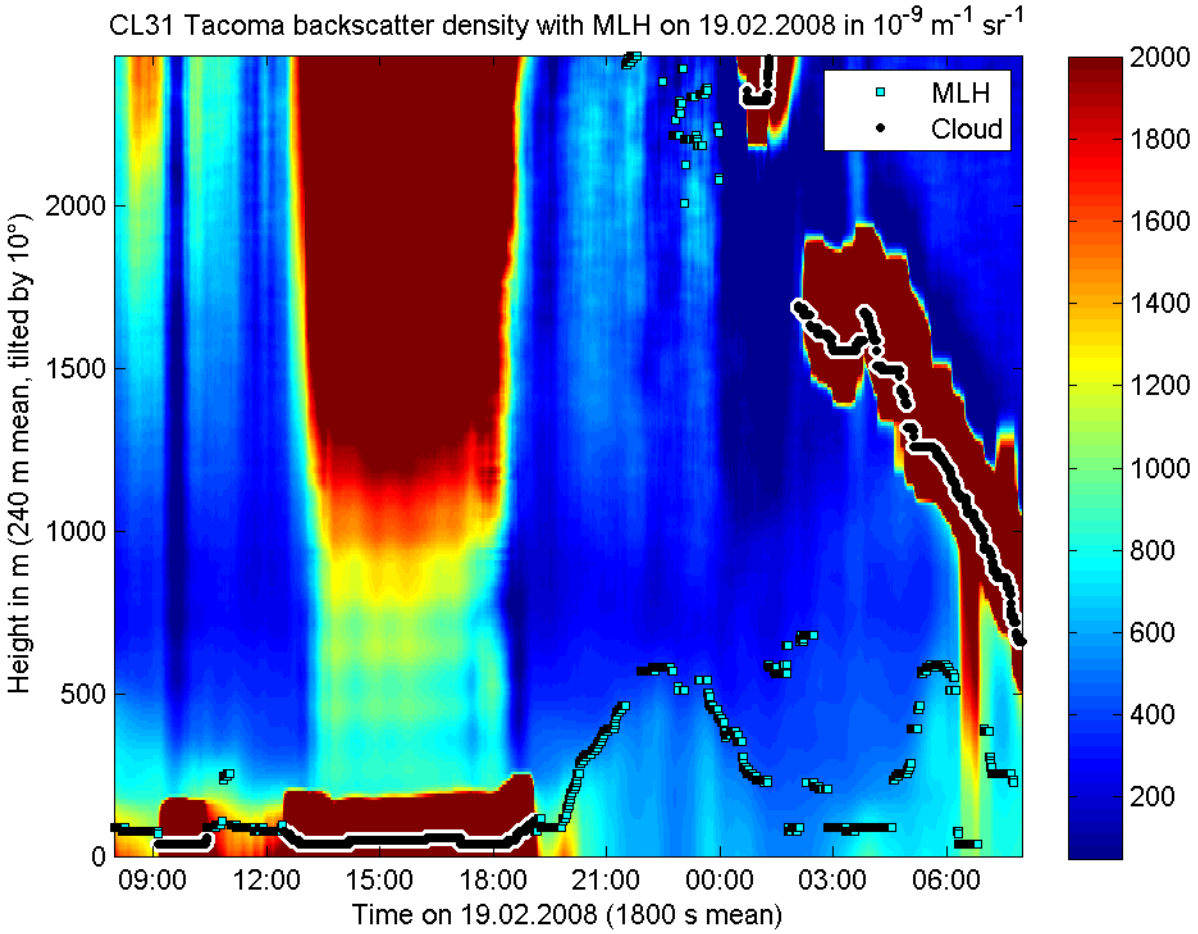
19.02.2008



- **Fog during the night, breaking up during morning**
- **Nice evolution of convective layer**
- **Weather front coming over in the evening**

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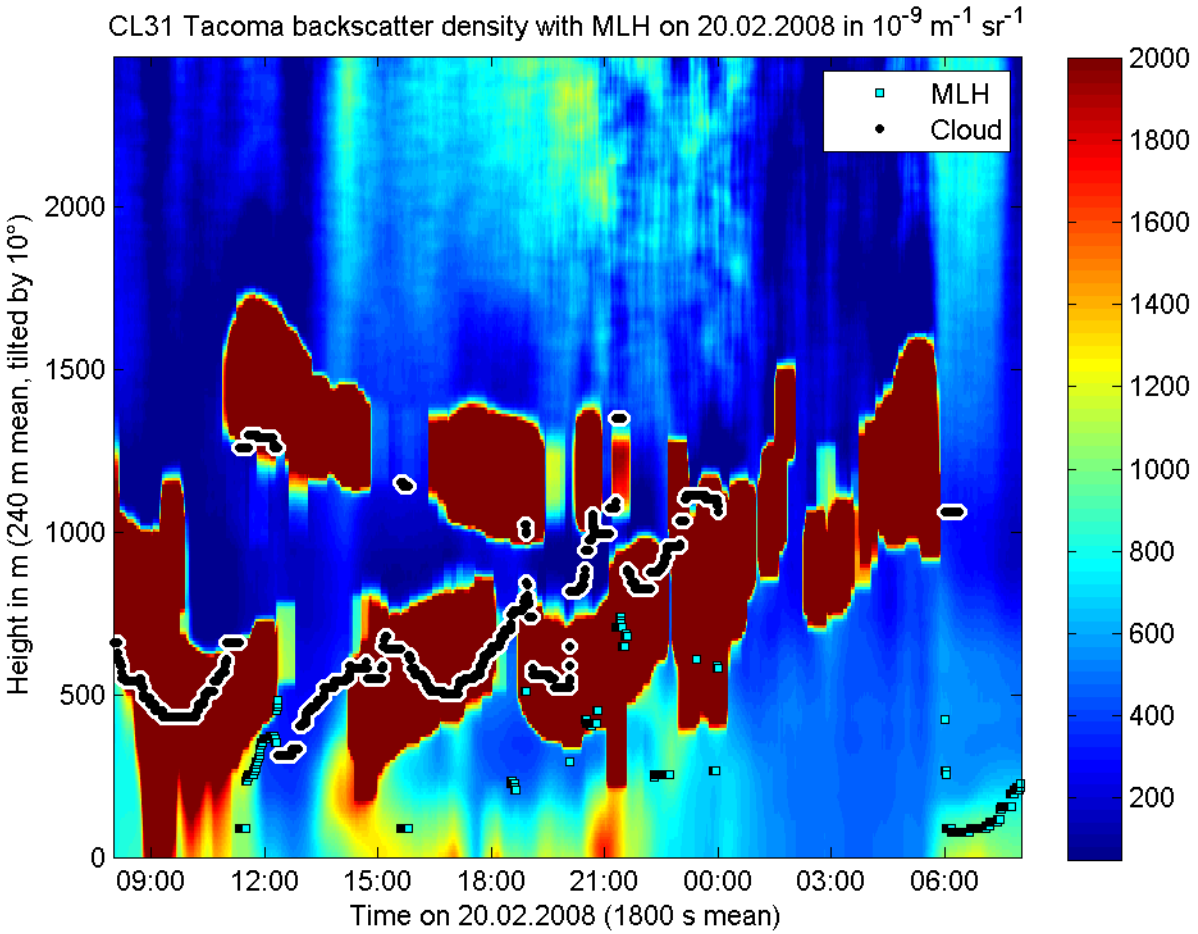
20.02.2008



- **Showers of precipitation during the day as cloud front moving**

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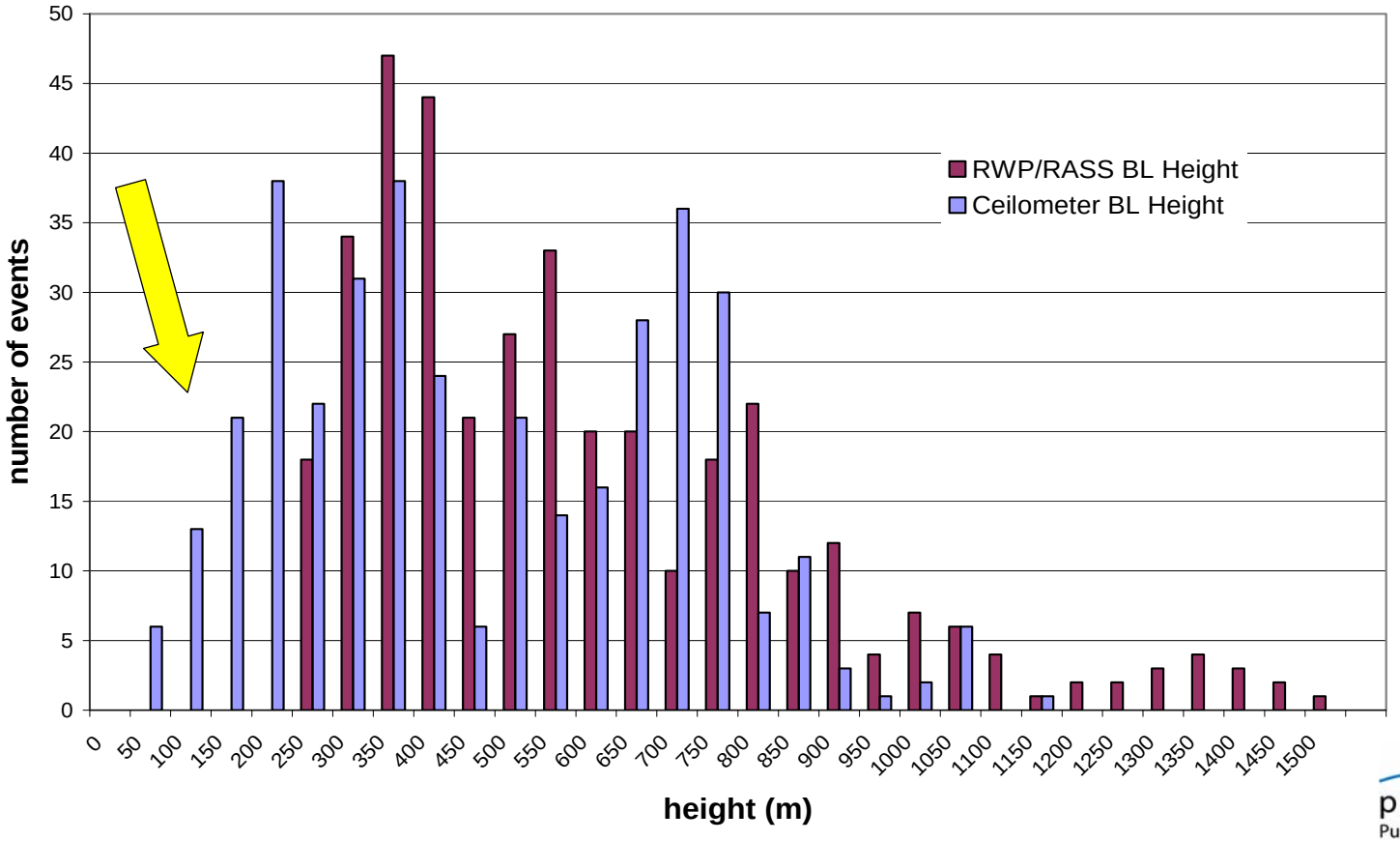
Results - Data Distribution

- **Ceilometer can detect BL heights below 200 m.**
- **The lack of ceilometer BL heights above 1,200 m appears to be a result of interference from clouds.**



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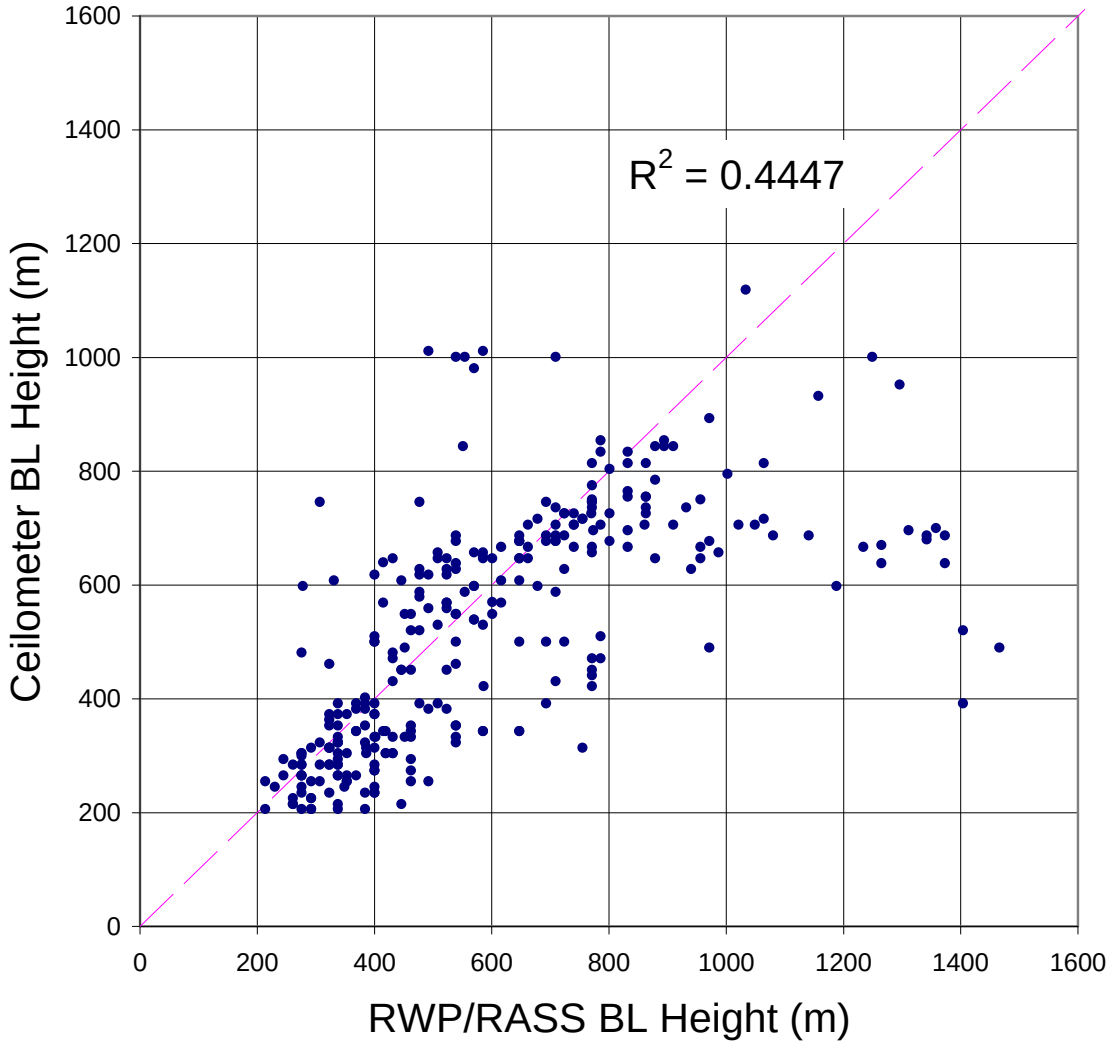
Results – Scatter Plots – All BL Height Data



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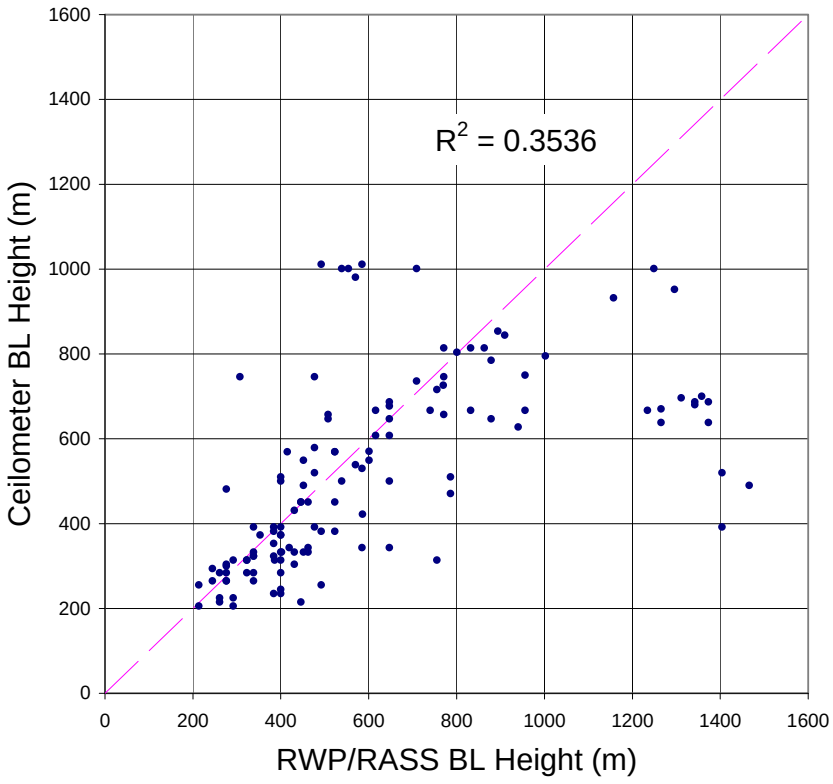
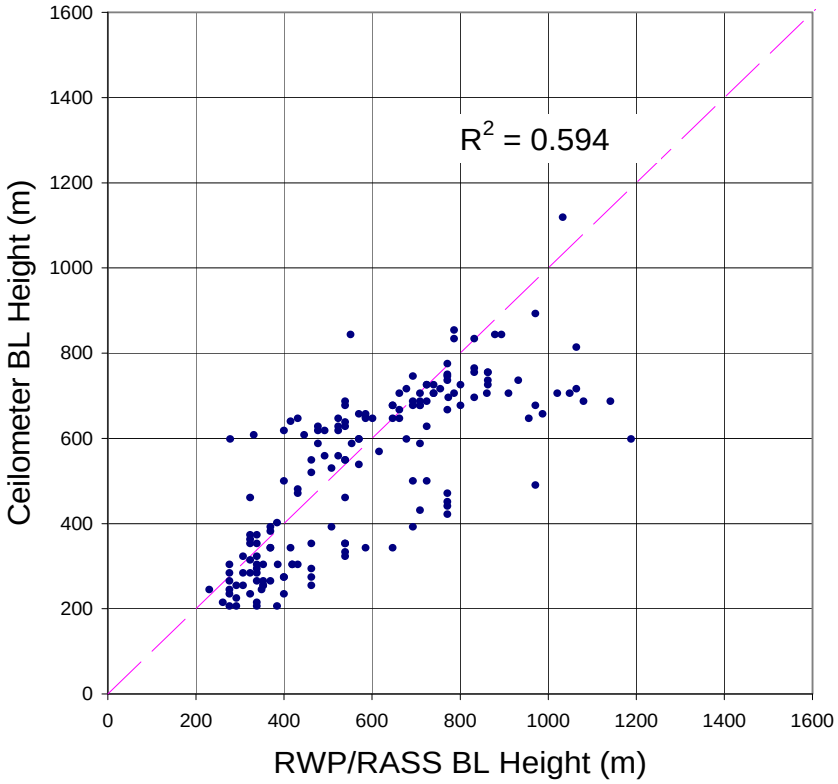
Results – Scatter Plots – Cloudy versus Clear Periods



- **Cloudy periods only; R^2 = 0.3536**



- **Clear periods only; R^2 = 0.594**

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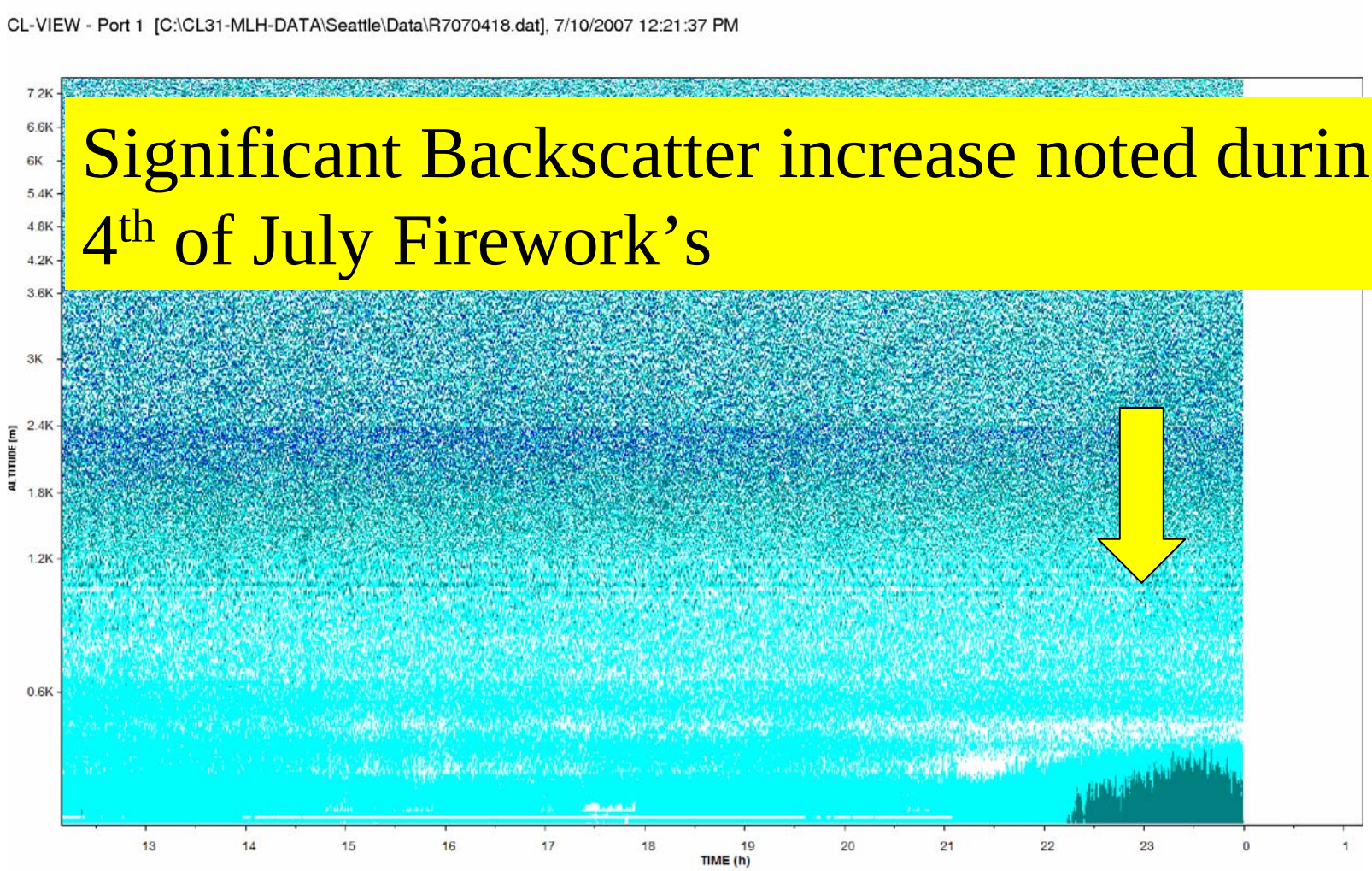
CL-VIEW graph 7/4/2007 Part 2, 12 PM – 12 AM



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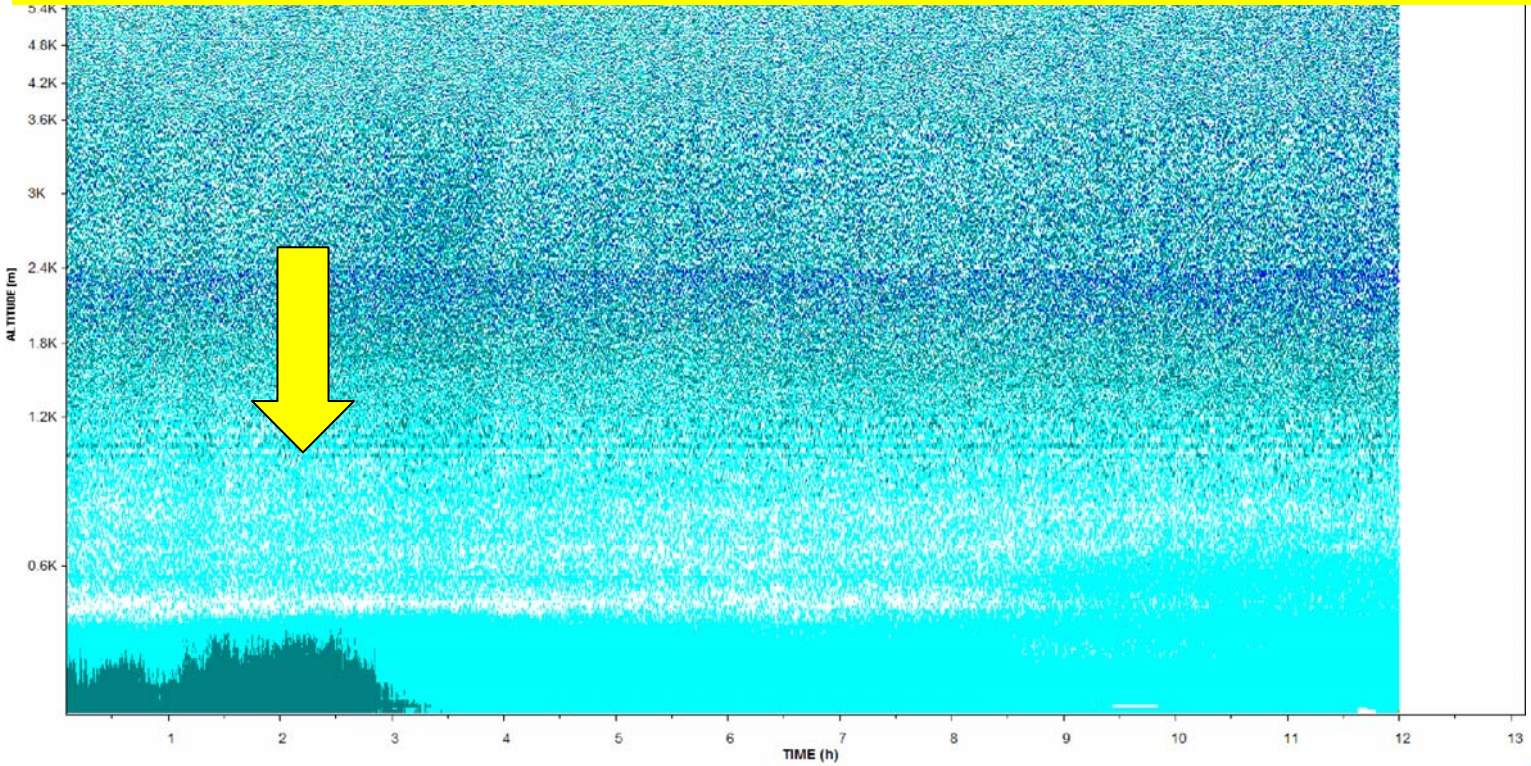
CL-VIEW graph 7/5/2007 Part 1, 12 AM – 12 PM

Significant Backscatter increase noted during 4th of July Firework's



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Summary

- **RWP/RASS and ceilometer BL heights were within 200 m of one another for 78% of the test period.**
- **The removal of cloudy periods resulted in**
  - **A significant improvement in RWP/RASS – ceilometer BL height correlation**
  - **A significant improvement in ceilometer bias (from 71 m to 55 m) to within the vertical resolution of the RWP/RASS (60 m).**
- **The low correlation between RWP/RASS BL heights and ceilometer BL heights during cloudy periods indicated that clouds may interfere with the ceilometer's calculation of BL heights.**

Findings

- **The ceilometer alone is useful for determining BL heights, especially during clear conditions.**
- **The ceilometer is useful for determining BL heights below 200 m, for which RWP wind, RASS T_v, and RWP moments data are unable to indicate such a low BL height.**
- **Using the ceilometer may be especially useful during the wintertime when BL heights are low.**
- **The ceilometer helps identify BL heights created by subtle atmospheric features that are not easy to discern in the RWP/RASS data.**

Findings- Logistics

- **CL- 31 is easy to deploy**
- **Cl-31 is affordable (~30K)**
- **Reliable**

Next Steps

- **Vaisala is completing it's evaluation and expects to declare the Mixing Ht capability operational in 2008**
- **Discuss possible solution to cloud interference**
- **Work with NWS, EPA and other to ensure Mixing Ht data is available from ASOS network.**
- **Develop an model validation experiment in EPA region 10**

Acknowledgements

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